

Operating System and Design (19CS2106A)

Advanced Lab- 6

Xv6 design, implementation, and customization.

1. System call tracing

System call tracing (moderate) ... You have to modify the xv6 kernel to print out a line when each system call is about to return, if the system call's number is set in the mask. The line should contain the process id, the name of the system call and the return value; you don't need to print the system call arguments.

You can use `strace` command to trace the execution of any executable.

The following example shows the output of `strace` for the Linux `ls` command.

Strace monitors the system calls and signals of a specific program. It is helpful when you do not have the source code and would like to debug the execution of a program. strace provides you the execution sequence of a binary from start to end.

BELOW COMMANDS ARE executed in putty :-----

strace ls,

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osd-190031187@team-osd-1
[osd-190031187@team-osd-1]$ strace ls
execve("/usr/bin/ls", ["ls"], 0x7fff4a07a6c0 /* 39 vars */) = 0
brk(NULL)                                = 0x977000
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7fe4bedc7000
access("/etc/ld.so.preload", R_OK)       = -1 ENOENT (No such file or directory)
open("/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
fstat(3, {st_mode=S_IFREG|0644, st_size=132159, ...}) = 0
mmap(NULL, 132159, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fe4beda6000
close(3)                                 = 0
open("/lib64/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\20\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=155744, ...}) = 0
mmap(NULL, 225216, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fe4be980000
mprotect(0x7fe4be9a4000, 2093056, PROT_NONE) = 0
mmap(0x7fe4beba3000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x23000) = 0x7fe4beba3000
mmap(0x7fe4beba5000, 6512, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fe4beba5000
close(3)                                 = 0
open("/lib64/libc.so.2", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\20\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=20048, ...}) = 0
mmap(NULL, 214412, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fe4be7b0000
mprotect(0x7fe4be77f000, 2093056, PROT_NONE) = 0
mmap(0x7fe4be79e000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x3000) = 0x7fe4be79e000
close(3)                                 = 0
open("/lib64/libacl.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0p\37\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=37064, ...}) = 0
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7fe4beda5000
mmap(NULL, 2130560, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fe4be572000
mprotect(0x7fe4be579000, 2097152, PROT_NONE) = 0
mmap(0x7fe4be779000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x7000) = 0x7fe4be779000
close(3)                                 = 0
open("/lib64/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\3\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\4\2\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=2156240, ...}) = 0
mmap(NULL, 3985920, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fe4bela4000
mprotect(0x7fe4be870000, 2097152, PROT_NONE) = 0
mmap(0x7fe4be890000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1c3000) = 0x7fe4be890000
mmap(0x7fe4be890000, 16896, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fe4be890000
close(3)                                 = 0
open("/lib64/libpcre.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\36\0\25\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=402384, ...}) = 0
mmap(NULL, 2494984, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fe4bdf42000
mprotect(0x7fe4bdfa2000, 2097152, PROT_NONE) = 0
mmap(0x7fe4bela2000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x60000) = 0x7fe4bela2000

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setat("/sys/fs/selinux", {st_mode=S_IFDIR|0755, st_size=0, ...}) = 0
brk(NULL)                               = 0x977000
brk(0x998000)                           = 0x998000
access("/etc/selinux/config", F_OK)     = 0
open("/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
stat(3, {st_mode=S_IFREG|0644, st_size=104176928, ...}) = 0
mmap(NULL, 106176928, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fe4b73da000
close(3)                                 = 0
ioctl(1, TCGETS, {B38400 oposit isig icanon echo ...}) = 0
ioctl(1, TIOCGWINSZ, {ws_row=46, ws_col=117, ws_xpixel=0, ws_ypixel=0}) = 0
openat(AT_FDCWD, "/dev/null", O_RDONLY|O_NONBLOCK|O_CLOEXEC|O_DIRECTORY) = 3
fcntl(3, /* O_RDWR */ 32768)           = 2560
getdents(3, /* 0 entries */ 32768)      = 0
close(3)                                 = 0
fsstat(1, {st_mode=S_IFCHR|0620, st_rdev=makedev(136, 53), ...}) = 0
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7fe4bedc6000
write(1, "190031187-xv6 dup2Example.c ex"...127190031187-xv6 dup2Example.c execDemo2.c fifo.c.save.1 half-bake.c mynice.c prg1.c t...
) = 112
write(1, "a.out\t EXEC\t execDemo.... 112a.out EXEC execDemo.c fifo.c.save.2 InLab8_1 mypipe prg2.c t...
) = 112
write(1, "aPIPE\t EXEC2\t fl.txt\t"... 111aPipe EXEC2 fl.txt fifo.c.save.3 InLab8_2 pipel.c prg3.c c...
) = 111
write(1, "attribute.c EXEC2.c\t f2."... 105attribute.c EXEC2.c f2.txt file.c killprocess.c pipe.c prg4.c e...
) = 105
write(1, "case.txt exec2Demo fi"... 129case.txt exec2Demo fibonacci.c filesystemchecker lab7_inlab1.c postlab7.c reader unline...
) = 129
write(1, "DemoOrphan EXRC.c\t fifo"... 122DemoOrphan EXRC.c fifo.c fork1Example.c lab7_inlab2.c prelab7 Reader.c c...
) = 122
write(1, "DemoOrphan.c execDemo fi"... 105DemoOrphan.c execDemo fifo.c.save fork2Example.c lru.c prelab7.c setjump.c welcome.c...
) = 105
close(1)                                 = 0
munmap(0x7fe4bedc6000, 4096)            = 0
close(2)                                 = 0
exit_group(0)                            = ?
+++ exited with 0 +++
lsdcpl90031187@team-osd -ls █
```

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[osd-190031187@team-osd ~]$ strace -e open ls
open("/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libcap.so.2", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libacl.so.1", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libpcre.so.1", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libdl.so.2", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libattr.so.1", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libpthread.so.0", O_RDONLY|O_CLOEXEC) = 3
open("/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
190031187-xv6 dup2Example.c execDemo2.c fifo.c.save.1 half-bake.c mynixe.c prgl.c shared-memory-xv6 welcome.s
a.out EXEC execDemo.c fifo.c.save.2 Inlab8.1 mypipe prg2.c signal.c writer
aPipe EXEC2 fl1.txt fifo.c.save.3 Inlab8.2 pipel.c prg3.c time.c Writer.c
attribute.c EXEC2.c f2.txt file.c killprcess.c pipe.c prg4.c times.c xv6
cse.txt exec2Demo fibinocci.c filesystemchecker lab7_inlab1.c postlab7.c reader unlink.c xv6-getpinfo
DemoOrphan EXEC.c fifo.c fork1Example.c lab7_inlab2.c prelab7 Reader.c unnamedpipe.c xv6-public
DemoOrphan.c execDemo fifo.c.save fork2Example.c lru.c prelab7.c setjump.c welcome.c
+++ exited with 0 +++
[osd-190031187@team-osd ~]$

```

```
strace -e trace=open,read ls /home
```

```

osd-190031187@team-osd:~$ strace -e trace=open,read ls /home
open("/etc/id.so.cache", O_RDONLY|O_CLOEXEC) = 3
open("/lib64/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\220\3\0\0\0\0\0\0....", 832) = 832
open("/lib64/libcap.so.2", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
open("/lib64/libacl.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
open("/lib64/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
open("/lib64/libpcr.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
open("/lib64/libdl.so.2", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
open("/lib64/libattr.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
open("/lib64/libpthread.so.0", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
open("/usr/lib/locale/locale-archive", O_RDONLY|O_CLOEXEC) = 3
5937-H coursefiles-csm coursefiles-maths osd-3168 osd-4940 osd-pool1 osd-skillcm peer-190030696 peer-user1 peer-user9
6239-H coursefiles-cse coursefiles-me osd-3509 osd-5262 osd-pool2 osd-skillhl peer-190030826 peer-user10 pradeepini
coursefiles coursefiles-ecm coursefiles-ph osd-3511 osd-5730 osd-pool3 osd-skillh2 peer-190030884 peer-user11 sadhana
coursefiles-arch coursefiles-ecm coursefiles-pharm osd-3531 osd-5937-H osd-pool4 peer-190030124 peer-190031126 peer-user2 sivamca05
coursefiles-arts coursefiles-eee coursefiles-phy osd-3658 osd-6239-H osd-pool5 peer-190030178 peer-190031457 peer-user3 skill-190030612
coursefiles-bca coursefiles-eng hadoop osd-3841 osd-advanced osd-pool6 peer-190030226 peer-190031483 peer-user4 skill-190030540
coursefiles-bt coursefiles-fed oracle osd-4277 osd-ecm osd-pool7 peer-190030271 peer-190031543 peer-user5 swapi
coursefiles-cms coursefiles-lm osd-1424 osd-4400 osd-faculty osd-pool8 peer-190030377 peer-190031795 peer-user6 teanoc
coursefiles-ce coursefiles-klubs osd-1834 osd-4480 osd-hydl osd-skillcl peer-190030423 peer-190031840 peer-user7 vagrant
coursefiles-chem coursefiles-law osd-2843 osd-4756 osd-hyd2 osd-skillc2 peer-190030635 peer-190031864 peer-user8 vishnu
+++ exited with 0 +++
osd-190031187@team-osd ~$

```

strace -o output.txt ls,

```

osd-190031187@team-osd:~$ strace -o output.txt ls
190031187-xv6 dup2Example.c execDemo2.c fifo.c.save.1 half-bake.c myniece.c prelab7.c setjmp.c welcome.c
a.out EXEC execDemo.c fifo.c.save.2 InLab8_1 mypipe prgl.c shared-memory-xv6 welcome.s
aPIPE EXEC2 fl.txt fifo.c.save.3 InLab8_2 output.txt prg2.c signal.c writer
attribute.c EXEC2.c f2.txt file.c killProcess.c pipe1.c prg3.c time.c Writer.c
cse.txt exec2Demo fibinoccl.c filesystemchecker lab7_inlab1.c pipe.c prg4.c times.c xv6
DemoOrphan EXEC.c fifo.c fork1Example.c lab7_inlab2.c postlab7.c reader unlink.c xv6-getpinfo
DemoOrphan.c execDemo fifo.c.save fork2Example.c lru.c prelab7 Reader.c unnamedpipe.c xv6-public
osd-190031187@team-osd ~$

```

cat output.txt

```

osd-190031187@team-osd:~$ cat output.txt
execve("/usr/bin/ls", ["ls"], 0x7ff3e438560 /* 39 vars */) = 0
brk(NULL) = 0x5f6000
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f2867e63000
access("/etc/id.so.prload", R_OK) = -1 ENOENT (No such file or directory)
open("/etc/id.so.cache", O_RDONLY|O_CLOEXEC) = 3
fstat(3, {st_mode=S_IFREG|0644, st_size=132159, ...}) = 0
mmap(NULL, 132159, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f2867e42000
close(3) = 0
open("/lib64/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\220\3\0\0\0\0\0\0....", 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=155744, ...}) = 0
mmap(NULL, 2255216, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2867a1c000
mprotect(0x7f2867a40000, 2093056, PROT_NONE) = 0
mmap(0x7f2867c3f000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x23000) = 0x7f2867c3f000
mmap(0x7f2867c41000, 6512, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f2867c41000
close(3) = 0
open("/lib64/libcap.so.2", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=20048, ...}) = 0
mmap(NULL, 2114112, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2867817000
mprotect(0x7f28678b000, 2093056, PROT_NONE) = 0
mmap(0x7f2867a1a000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x3000) = 0x7f2867a1a000
close(3) = 0
open("/lib64/libacl.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=37064, ...}) = 0
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f2867e41000
mmap(0x7f2867e5000, 2097152, PROT_NONE) = 0
mprotect(0x7f2867e5000, 2097152, PROT_NONE) = 0
mmap(0x7f2867815000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x7000) = 0x7f2867815000
close(3) = 0
open("/lib64/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=2156240, ...}) = 0
mmap(NULL, 3985920, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2867240000
mprotect(0x7f2867403000, 2097152, PROT_NONE) = 0
mmap(0x7f2867603000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1c3000) = 0x7f2867603000
mmap(0x7f2867609000, 16896, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f2867609000
close(3) = 0
open("/lib64/libpcr.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\20\26\0\0\0\0\0\0....", 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=402384, ...}) = 0
mmap(NULL, 2494984, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2866fde000
mprotect(0x7f286703e000, 2097152, PROT_NONE) = 0
mmap(0x7f286723e000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x60000) = 0x7f286723e000

```


[illegible]

```
strace -p 1725 -o output.txt,
```

 osd-190031187@team-osd:~

```
[osd-190031187@team-osd ~]$ strace -p 1725 -o output.txt
strace: attach: ptrace(PTRACE_SEIZE, 1725): No such process
[osd-190031187@team-osd ~]$
```

```
strace -t -e open ls /home,
```

[illegible]

```
strace -r ls,
```

```

osd-190031187@team-osd-1
[osd-190031187@team-osd ~]$ strace -r ls
0.000000 execve("/usr/bin/ls", ["ls"], 0x7fff2e7cf268 /* 39 vars */) = 0
0.000665 brk(NULL)                = 0x24c9000
0.000093 mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f85c8327000
0.000104 access("/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or directory)
0.000217 open("/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
0.000087 fstat(3, {st_mode=S_IFREG|0644, st_size=132159, ...}) = 0
0.000086 mmap(NULL, 132159, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f85c8306000
0.000057 close(3)                  = 0
0.000067 open("/lib64/libselinux.so.1", O_RDONLY|O_CLOEXEC) = 3
0.000064 read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\220j\0\0\0\0\0\0"... , 832) = 832
0.000066 fstat(3, {st_mode=S_IFREG|0755, st_size=155744, ...}) = 0
0.000052 mmap(NULL, 2255216, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f85c7ee0000
0.000061 mprotect(0x7f85c7f04000, 2093056, PROT_NONE) = 0
0.000053 mmap(0x7f85c8103000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x23000) = 0x7f85c8103000
0.000075 mmap(0x7f85c8105000, 6512, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f85c8105000
0.000087 close(3)                  = 0
0.000075 open("/lib64/libcap.so.2", O_RDONLY|O_CLOEXEC) = 3
0.000059 read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\20\26\0\0\0\0\0\0"... , 832) = 832
0.000050 fstat(3, {st_mode=S_IFREG|0755, st_size=20048, ...}) = 0
0.000060 mmap(NULL, 2114112, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f85c7cd8000
0.000059 mprotect(0x7f85c7cdf000, 2093056, PROT_NONE) = 0
0.000052 mprotect(0x7f85c7ede000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x3000) = 0x7f85c7ede000
0.000075 close(3)                  = 0
0.000065 open("/lib64/libacl.so.1", O_RDONLY|O_CLOEXEC) = 3
0.000075 read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\0p\37\0\0\0\0\0\0"... , 832) = 832
0.000061 fstat(3, {st_mode=S_IFREG|0755, st_size=37064, ...}) = 0
0.000056 mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f85c8305000
0.000051 mmap(NULL, 2130560, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f85c7ad2000
0.000057 mprotect(0x7f85c7ad9000, 2097152, PROT_NONE) = 0
0.000064 mmap(0x7f85c7cd9000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x7000) = 0x7f85c7cd9000
0.000087 close(3)                  = 0
0.000057 open("/lib64/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
0.000057 read(3, "\177ELFv2\1\1\3\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\2\2\0\0\0\0\0\0"... , 832) = 832
0.000062 fstat(3, {st_mode=S_IFREG|0755, st_size=2156240, ...}) = 0
0.000058 mmap(NULL, 3585920, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f85c7704000
0.000052 mprotect(0x7f85c78c000, 2097152, PROT_NONE) = 0
0.000061 mmap(0x7f85c7ac7000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0xc13000) = 0x7f85c7ac7000
0.000069 mmap(0x7f85c7acd000, 16896, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f85c7acd000
0.000067 close(3)                  = 0
0.000059 open("/lib64/libpcrcr.so.1", O_RDONLY|O_CLOEXEC) = 3
0.000076 read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\36\0\25\0\0\0\0\0\0"... , 832) = 832
0.000060 fstat(3, {st_mode=S_IFREG|0755, st_size=402384, ...}) = 0
0.000058 mmap(NULL, 2494984, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f85c74a2000
0.000059 mprotect(0x7f85c7502000, 2097152, PROT_NONE) = 0
0.000058 mmap(0x7f85c7702000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x60000) = 0x7f85c7702000
osd-190031187@team-osd-1
close(3)                            = 0
open("/lib64/libdl.so.2", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\0p\16\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=19248, ...}) = 0
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f2867e40000
mmap(NULL, 2197948, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2866dd4000
mprotect(0x7f2866ddc000, 2097152, PROT_NONE) = 0
mmap(0x7f2866fde000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x2000) = 0x7f2866fde000
close(3)                            = 0
open("/lib64/libattr.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\32\0\23\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=19896, ...}) = 0
mmap(NULL, 2113904, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2866bd5000
mprotect(0x7f2866bd9000, 2093056, PROT_NONE) = 0
mmap(0x7f2866edd000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x3000) = 0x7f2866edd000
close(3)                            = 0
open("/lib64/libpthread.so.0", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELFv2\1\1\0\0\0\0\0\0\0\0\0\0\3\0\0\0\1\0\0\0\0\20\0\0\0\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=142144, ...}) = 0
mmap(NULL, 2208904, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f28669b9000
mprotect(0x7f28669bd000, 2093056, PROT_NONE) = 0
mmap(0x7f2866bec000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0xc16000) = 0x7f2866bec000
mmap(0x7f2866ebd1000, 13448, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f2866ebd100
close(3)                            = 0
mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f2867e3f000
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f2867e3d000
arch_prctl_1(RCHX_SET_FS, 0x7f2867e3b040) = 0
mprotect(0x7f2867e03000, 16384, PROT_READ) = 0
mprotect(0x7f2866bcf000, 4096, PROT_READ) = 0
mprotect(0x7f2866ddb000, 4096, PROT_READ) = 0
mprotect(0x7f2866fdc000, 4096, PROT_READ) = 0
mprotect(0x7f286723e000, 4096, PROT_READ) = 0
mprotect(0x7f2867815000, 4096, PROT_READ) = 0
mprotect(0x7f2867a1a000, 4096, PROT_READ) = 0
mprotect(0x7f2867c13f000, 4096, PROT_READ) = 0
mprotect(0x61a000, 4096, PROT_READ) = 0
mprotect(0x7f2867e64000, 4096, PROT_READ) = 0
mmap(0x7f2867e42000, 132159)         = 0
set_tid_address(0x7f2867e3db00)      = 32756
set_prlimit_list(0x7f2867e3db00, 24) = 0
rt_sigaction(SIGRTMIN, {sa_handler=0x7f28669bf860, sa_mask=[], sa_flags=SA_RESTORER|SA_SIGINFO, sa_restorer=0x7f28669cb630}, NULL, 8) = 0
rt_sigaction(SIGRT_1, {sa_handler=0x7f28669bf860, sa_mask=[], sa_flags=SA_RESTORER|SA_SIGINFO, sa_restorer=0x7f28669cb630}, NULL, 8) = 0
rt_sigprocmask(SIG_UNBLOCK, [RTMIN RT_1], NULL, 8) = 0
getrlimit(RLIMIT_STACK, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
stats("/sys/fs/selinux", {f_type=SELINUX_MAGIC, f_bsize=4096, f_blocks=0, f_bfree=
```

strace -c ls /home

```
osd-190031187@team-osd:~$ strace -c ls /home
5937-H coursefiles-com coursefiles-maths osd-3168 osd-4940 osd-pool1 osd-skillc2 peer-190030696 peer-user1 peer-user9
6239-H coursefiles-cse coursefiles-me osd-3509 osd-5262 osd-pool2 osd-skillh1 peer-190030826 peer-user10 pradeepini
coursefiles coursefiles-ece coursefiles-pe osd-3511 osd-5730 osd-pool3 osd-skillh2 peer-190030884 peer-user11 sadhana
coursefiles-arch coursefiles-ecm coursefiles-pharm osd-3531 osd-5937-H osd-pool4 peer-190030124 peer-190031126 peer-user2 sivamca05
coursefiles-arts coursefiles-eee coursefiles-phy osd-3658 osd-6239-H osd-pool5 peer-190030178 peer-190031457 peer-user3 skill-180030612
coursefiles-bca coursefiles-eng hadoop osd-3841 osd-advanced osd-pool6 peer-190030226 peer-190031483 peer-user4 skill-190330540
coursefiles-bt coursefiles-fed oracle osd-4277 osd-ecm osd-pool7 peer-190030271 peer-190031543 peer-user5 swapl
coursefiles-cams coursefiles-hm osd-1424 osd-4400 osd-faculty osd-pool8 peer-190030377 peer-190031795 peer-user6 teamos
coursefiles-ce coursefiles-klubs osd-1834 osd-4480 osd-hyd1 osd-skillc1 peer-190030623 peer-190031840 peer-user7 vagrant
coursefiles-chem coursefiles-law osd-2843 osd-4756 osd-hyd2 osd-skillc2 peer-190030635 peer-190031864 peer-user8 vishnu
% time seconds usecs/call calls errors syscall
-----
54.10 0.000779 389 2 statfs
22.50 0.000324 162 2 stat
14.79 0.000213 106 2 l access
2.71 0.000039 19 2 getdents
1.60 0.000023 23 1 openat
1.32 0.000019 1 10 open
0.97 0.000014 4 3 bix
0.62 0.000009 0 27 mmap
0.62 0.000009 4 2 loctl
0.49 0.000007 0 13 close
0.28 0.000004 0 11 fstat
0.00 0.000000 0 8 read
0.00 0.000000 0 10 write
0.00 0.000000 0 18 mprotect
0.00 0.000000 0 2 munmap
0.00 0.000000 0 2 rt_sigaction
0.00 0.000000 0 1 rt_sigprocmask
0.00 0.000000 0 1 execve
0.00 0.000000 0 1 getrlimit
0.00 0.000000 0 1 arch_prctl
0.00 0.000000 0 1 set_tid_address
0.00 0.000000 0 1 set_robust_list
100.00 0.001440 121 1 total
[osd-190031187@team-osd ~]$
```

2. Add support for symbolic links

Symbolic links are basically advanced shortcuts. Create a symbolic link to an individual file or folder, and that link will appear to be the same as the file or folder to Windows—even though it's just a link pointing at the file or folder. A symbolic link is simply a file with a special type (e.g., T_SYMLINK instead of T_FILE or T_DIR) whose contents contain the path being linked to. Turn in a short writeup of how you would change xv6 to support symlinks. Symbolic links were already present by 1978 in minicomputer operating systems from DEC and Data General's RDOS. Today they are supported by the POSIX operating system standard, most Unix-like operating systems such as FreeBSD, Linux, and macOS.

EXAMPLE PROGRAM FOR SYMBOLICLINK AND ITS EXECUTION

```
osd-190031187@team-osd:~$ nano -w symlink.c
GNU nano 2.3.1 File: symlink.c
#define _POSIX_SOURCE 2
#include <fcntl.h>
#include <sys/stat.h>
#include <sys/types.h>
#include <unistd.h>
#include <stdlib.h>
#include <stdio.h>

main()
{
    char fn[]="test.file";
    char sln[]="test.sysmlink";
    int fd;
    if((fd=creat(fn,S_IWUSR))<0)
        perror("creat() error");
    else{
        close(fd);
        puts("befor symlink()");
        system("ls -il test.*");
        if(symlink(fn,sln)!=0){
            perror("symlink error");
            unlink(fn);
        }
        else
        {
            puts("after symlink()");
            system("ls -il test.*");
            unlink(fn);
            puts("after first unlink()");
            system("ls -il test.*");
            unlink(sln);
        }
    }
}
```

OUTPUT

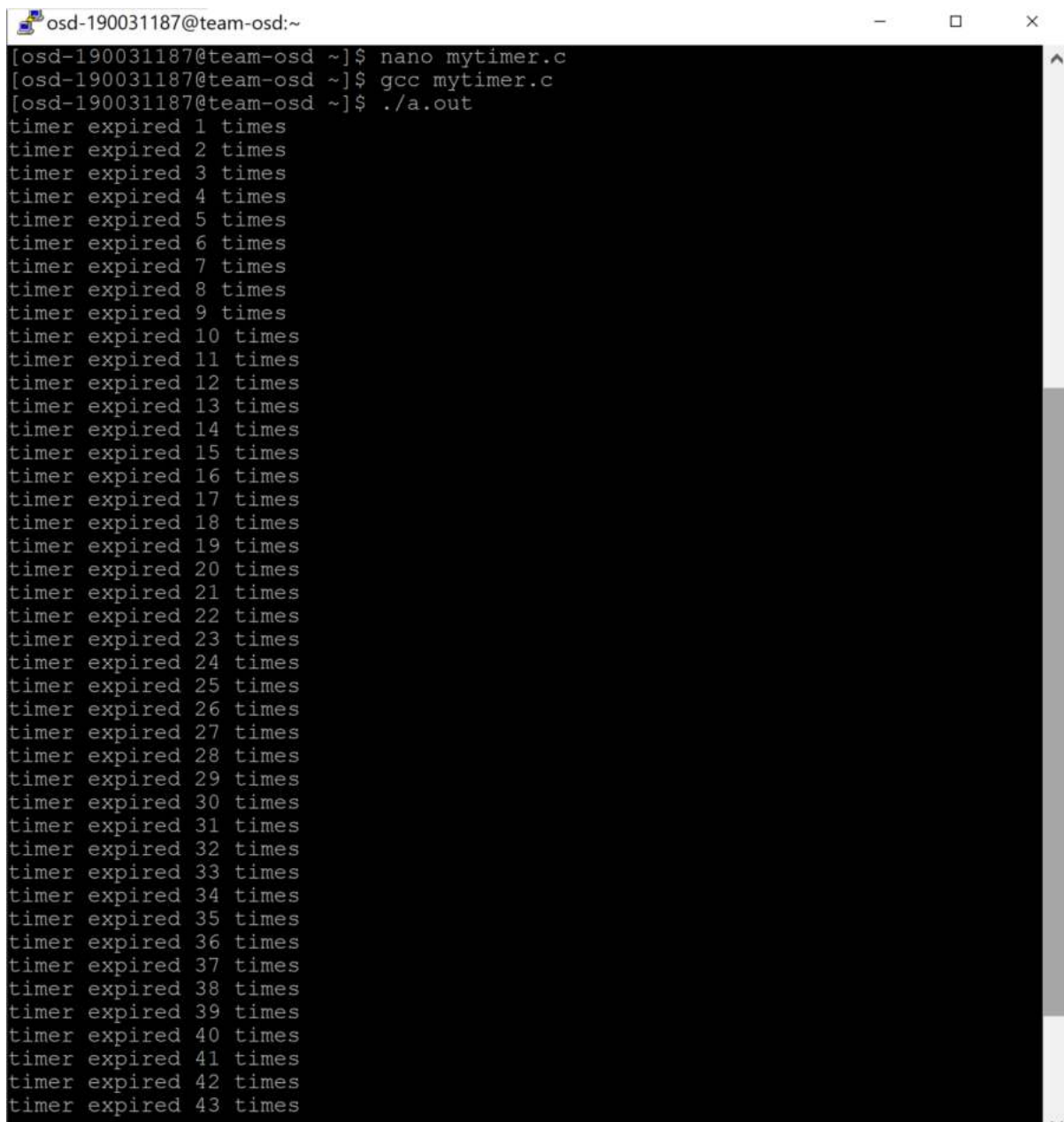
```
osd-190031187@team-osd:~  
[osd-190031187@team-osd ~]$ nano symlink.c  
[osd-190031187@team-osd ~]$ gcc symlink.c  
[osd-190031187@team-osd ~]$ ./a.out  
befor symlink()  
1126320364 --w-----. 1 osd-190031187 osd-190031187 0 Nov  2 20:58 test.file  
after symlink()  
1126320364 --w-----. 1 osd-190031187 osd-190031187 0 Nov  2 20:58 test.file  
1126320365 lrwxrwxrwx. 1 osd-190031187 osd-190031187 9 Nov  2 20:58 test.syse  
after first unlink()  
1126320365 lrwxrwxrwx. 1 osd-190031187 osd-190031187 9 Nov  2 20:58 test.syse  
[osd-190031187@team-osd ~]$
```

UNIX system programming

1. program using timer

```
osd-190031187@team-osd:~  
GNU nano 2.3.1 File: mytimer.c  
#include<signal.h>  
#include<stdio.h>  
#include<string.h>  
#include<sys/time.h>  
  
void timer_handler (int signum)  
{  
    static int count=0;  
    printf("timer expired %d times\n",++count);  
}  
  
int main()  
{  
    struct sigaction sa;  
    struct itimerval timer;  
    memset(&sa,0,sizeof(sa));  
    sa.sa_handler=&timer_handler;  
    sigaction(SIGVTALRM,&sa,NULL);  
    timer.it_value.tv_sec=1;  
    timer.it_value.tv_usec=0;  
    timer.it_interval.tv_sec=1;  
    timer.it_interval.tv_usec=0;  
    setitimer(ITIMER_VIRTUAL,&timer,NULL);  
    while(1);  
    sleep(1);  
}
```


OUTPUT

A terminal window titled 'osd-190031187@team-osd:~' with standard window controls. The terminal shows the following commands and output:

```
[osd-190031187@team-osd ~]$ nano mytimer.c
[osd-190031187@team-osd ~]$ gcc mytimer.c
[osd-190031187@team-osd ~]$ ./a.out
timer expired 1 times
timer expired 2 times
timer expired 3 times
timer expired 4 times
timer expired 5 times
timer expired 6 times
timer expired 7 times
timer expired 8 times
timer expired 9 times
timer expired 10 times
timer expired 11 times
timer expired 12 times
timer expired 13 times
timer expired 14 times
timer expired 15 times
timer expired 16 times
timer expired 17 times
timer expired 18 times
timer expired 19 times
timer expired 20 times
timer expired 21 times
timer expired 22 times
timer expired 23 times
timer expired 24 times
timer expired 25 times
timer expired 26 times
timer expired 27 times
timer expired 28 times
timer expired 29 times
timer expired 30 times
timer expired 31 times
timer expired 32 times
timer expired 33 times
timer expired 34 times
timer expired 35 times
timer expired 36 times
timer expired 37 times
timer expired 38 times
timer expired 39 times
timer expired 40 times
timer expired 41 times
timer expired 42 times
timer expired 43 times
```

2. program using alarm call


```

osd-190031187@team-osd:~
GNU nano 2.3.1      File: sigalarm.c

#include<stdio.h>
#include<unistd.h>
#include<signal.h>

void sig_handler(int signum)
{
    if(signum==SIGALRM){
        printf("Inside handler function for SIGALRM\n");
        alarm(2);
    }
    if(signum==SIGINT){
        printf("\nSnoozing for 5 seconds..\n");
        alarm(5);
    }
}

int main()
{
    int i;
    signal(SIGALRM,sig_handler);
    signal(SIGINT,sig_handler);
    alarm(2);
    for(i=1;;i++)
    {
        printf("%d: Inside Main function\n",i);
        pause();
    }
    return 0;
}

```

OUTPUT

```

osd-190031187@team-osd:~
[osd-190031187@team-osd ~]$ nano sigalarm.c
[osd-190031187@team-osd ~]$ gcc sigalarm.c
[osd-190031187@team-osd ~]$ ./a.out
1: Inside Main function
Inside handler function for SIGALRM
2: Inside Main function
Inside handler function for SIGALRM
3: Inside Main function
Inside handler function for SIGALRM
4: Inside Main function
Inside handler function for SIGALRM
5: Inside Main function
Inside handler function for SIGALRM
6: Inside Main function
Inside handler function for SIGALRM
7: Inside Main function
Inside handler function for SIGALRM
8: Inside Main function
Inside handler function for SIGALRM
9: Inside Main function
Inside handler function for SIGALRM
10: Inside Main function
Inside handler function for SIGALRM
11: Inside Main function
Inside handler function for SIGALRM
12: Inside Main function
Inside handler function for SIGALRM
13: Inside Main function
Inside handler function for SIGALRM
14: Inside Main function
Inside handler function for SIGALRM
15: Inside Main function
Inside handler function for SIGALRM
16: Inside Main function
Inside handler function for SIGALRM
17: Inside Main function
Inside handler function for SIGALRM
18: Inside Main function
Inside handler function for SIGALRM
19: Inside Main function
^C
Snoozing for 5 seconds..
20: Inside Main function
^C
Snoozing for 5 seconds..
21: Inside Main function

```

```

Inside handler function for SIGALRM
22: Inside Main function
Inside handler function for SIGALRM
23: Inside Main function
Inside handler function for SIGALRM
24: Inside Main function
Inside handler function for SIGALRM
25: Inside Main function
^Z
[1]+  Stopped                  ./a.out
[osd-190031187@team-osd ~]$

```

3. program invoking profil system call

The `profil()` function provides CPU-use statistics by profiling the amount of CPU time expended by a program. The `profil()` function generates the statistics by creating an execution histogram for a current process.

```

osd-190031187@team-osd:~
GNU nano 2.3.1      File: profil.c
#include<stdio.h>
#include<stdlib.h>
#include<string.h>
#include<sys/types.h>
#include<unistd.h>
#include<execinfo.h>

size_t offset=(size_t)0x08000000u;

size_t bufsize=(size_t)0x00100000u;

typedef unsigned short profil_pc_t;

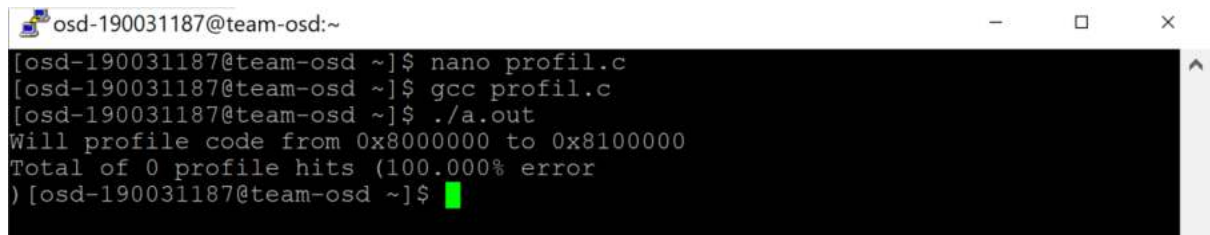
int foo;
void do_adds(void){
    int i;
    for(i=0;i<100*1000*1000;i++){
        foo=foo+(1+i);
    }
}
void do_divides(void){
    int i;
    for(i=0;i<100*1000*1000;i++){
        foo=foo/(1+i);
    }
}
void code_under_test(void){
    do_adds();
    do_divides();
}

int main()
{
    profil_pc_t *buf;
    printf("Will profile code from %p to %p\n", (void *)offset, (void *)0);
    buf=(profil_pc_t *)malloc(sizeof(profil_pc_t)*bufsize);
    profil(buf,bufsize,offset,65536*2);
    code_under_test();

    profil(0,0,0,0);
    {
        size_t i;
        long int total=0;
        for(i=0;i<bufsize;i++) total+=buf[i];
        printf("Total of %d profile hits  (%.3f%% error\n",
            (int)total,100.0/(1+total));
        for(i=0;i<bufsize;i++)
            if(buf[i]!=0){
                void *ptr=(void *) (offset+i);
                char **names=backtrace_symbols(&ptr,1);
                printf("%.3f%% at pc %p: %s\n",
                    100.0*buf[i]/total,ptr,names[0]);
                free(names);
            }
        }
    free(buf);
    return 0;
}

```

OUTPUT

A terminal window with a black background and white text. The window title is 'osd-190031187@team-osd:~'. The terminal shows the following commands and output:

```
[osd-190031187@team-osd ~]$ nano profil.c
[osd-190031187@team-osd ~]$ gcc profil.c
[osd-190031187@team-osd ~]$ ./a.out
Will profile code from 0x8000000 to 0x8100000
Total of 0 profile hits (100.000% error
) [osd-190031187@team-osd ~]$
```

The cursor is a green block at the end of the last line.